CNR-IRCrES Working Paper

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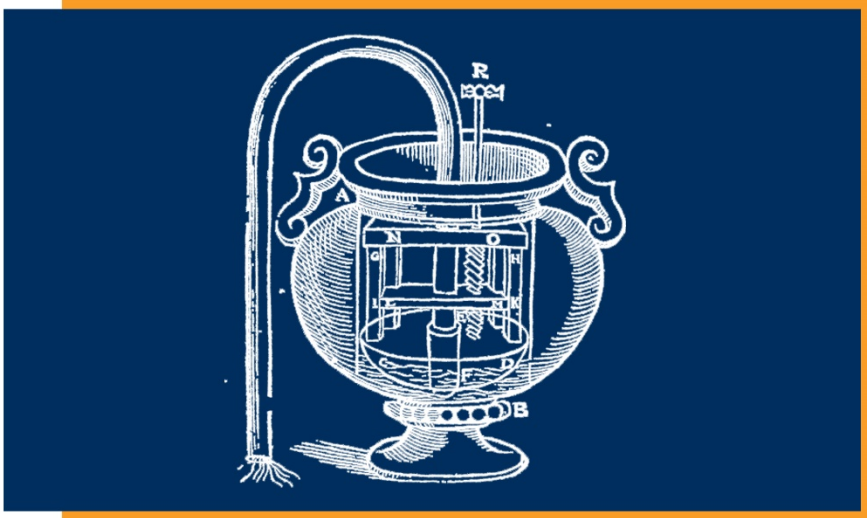

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Ugo Finardi
Jeanne C.M. Vallette d'Osia

CNR IRCrES
Istituto di Ricerca sulla Crescita Economica Sostenibile

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Direttore	Elena Ragazzi
Direzione	CNR-IRCrES *Istituto di Ricerca sulla Crescita Economica Sostenibile* Strada delle Cacce 73, 10135 Torino, Italy Tel. +39 011 3977612 segreteria@ircres.cnr.it www.ircres.cnr.it
Sede di Roma	Via dei Taurini 19, 00185 Roma, Italy Tel. +39 06 49937809 / Fax +39 06 49937808
Sede di Milano	Via Corti 12, 20121 Milano, Italy Tel. +39 02 23699501 / Fax +39 02 23699530
Sede di Genova	Corso Ferdinando Maria Perrone 24, 16152 Genova, Italy Tel. +39 010 6598798

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CNR-IRCrES Working Paper 7/2025

Mapping international collaboration in Nanosciences and Nanotechnologies: a bibliometric and econometric study of South African research

UGO FINARDI, AND JEANNE C.M. VALLETTE D'OSIA*

CNR-IRCrES, Consiglio Nazionale delle Ricerche, Istituto di Ricerca sulla Crescita Economica Sostenibile, strada delle Cacce 73, 10135 Torino, Italia

*Corresponding author: jeannecharlottemarievallettedosia@cnr.it

ABSTRACT

This paper examines the dynamics of national and international research collaboration in nanosciences and nanotechnologies (NSTs) in South Africa, a country studied for its distinctive position – at continental and world level – in global scientific production and cross-border partnerships. The main objective is to map collaboration patterns and identify the key determinants of international scientific co-productions.

We employ both bibliometric and econometric approaches. The bibliometric analysis, based on publication data from the Clarivate Web of Science®, captures trends in internal and external collaboration, while the econometric analysis applies a gravity model to our dataset, which links publication records with country-level information from the CEPII gravity database, the ARD Data Set and the IGO Data Set.

Descriptive statistical findings reveal a shift over time, with international collaboration outpacing domestic collaboration. As for the econometric analysis, geographic proximity exerts the strongest positive influence on collaboration intensity, with higher levels of scientific production in partner countries positively associated with collaboration. In addition, shared membership in intergovernmental organizations emerges as the only other relevant factor in explaining co-production. These results highlight both the global integration of South African NSTs research and the persistent structural barriers that shape its collaborative landscape.

KEYWORDS: nanosciences; nanotechnology; Africa; South Africa; international collaboration; scientific research.

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CONTENT

1. INTRODUCTION

Nanosciences and nanotechnologies (NSTs from now on) have been regarded, since their inception, as a relevant scientific and technological field (H. Chen et al., 2013) (Roco & Bainbridge, 2002) (Finardi & Lamberti, 2021). Their nature of converging field, where different disciplines – chemistry, physics, biology, materials sciences – meet in order to exploit the features of the matter at the scale of nanometres opened the field to the interest of scientists, engineers, technologists, as well as to that of the industries and firms (Mangematin & Walsh, 2012) (Balzani, 2005) (Finardi, 2013).

After almost three decades from the beginning of scientific exploration in the field, NSTs have evolved from a promise for research, technology and innovation to a well assessed field, with an overwhelming corpus of scientific literature and several applications in technologies exploited in every day's life (Finardi, 2023).

These features make NSTs an ideal subject to explore with the aim of disentangling the features of scientific research of a Country, such as the distribution of research activities in the Country or the national and international collaborations. NSTs, in fact, are both a highly scientific and technological advanced field and a diffused source of innovations for application in the production process.

Given these facts, the present work aims at exploiting NSTs as an interpretive key to understanding the collaboration structure of a specific country. NSTs are by one hand relevant *per se* as a research field, and by the other hand are an ideal instrument to explore research collaboration given this nature of a field in transition between specialistic top level research and wide diffusion.

The present work focuses on the relevant case of an African country, South Africa. South Africa is both a relevant subject to explore if one wants to test the use of NSTs as a measure of collaboration, and a relevant case by itself. South Africa is by far the most important sub-Saharan African country in terms of scientific production (Jeenah & Pouris, 2008) (Makhoba & Pouris, 2016) (Sooryamoorthy, 2019). South Africa is also a member of the BRICS group of countries, thus being part of an international network (Finardi, 2015) (Finardi & Buratti, 2016).

Thus, the aim of the present work is responding to the following research questions: which are the distinctive features of the international research collaboration, and of the internal structure of the scientific production, of a relevant case of sub-Saharan African country, namely South Africa? What do these features depend on? This article tries to respond to this question by exploiting a bibliometric methodology, based on a dataset built starting from Clarivate Web of Science®, as well as an econometric analysis using several other supplementary data.

The main results show that the most relevant factor affecting collaboration is geographical distance between countries. Other explored determinants, such as difference in time zone, colonial ties or language, seem not to have effect, while the only other variable that affects collaboration (besides the trivial one, total scientific production of partners) is the common membership in International Governmental Organizations.

While international scientific collaboration has been studied in various contexts, research on Africa remains scarce, and work focusing specifically on NSTs is even more limited. By concentrating on this field, our study deepens the understanding of collaboration dynamics in an underexplored geographic area. In addition, we add originality through the combined use of bibliometric and econometric approaches, which allows to capture both descriptive patterns and causal determinants of collaboration.

This article is organized as follows. Section 2 contains a literature overview, presenting literature on the topics of the features of NSTs and of the nature and assessment of international research collaboration. Section 3 presents the methodological strategy followed in the paper, while section 4 presents the results of our bibliometric analysis. In turn, section 5, presents the econometric analysis based on a gravity model as well as the discussion of results. Eventually, section 6 summarizes the findings and the paths of further analysis.

2. LITERATURE OVERVIEW

This section presents the description of a selection of relevant scientific literature on the topics that are most relevant in the context of the present work. The first subsection describes the features and the historical path of NSTs is presented. A second subsection presents instead a more methodological literature on the determinants and features of international research collaboration.

2.1. Nanotechnologies and nanosciences: introduction and features

NSTs were first conceptually outlined by Richard P. Feynman in 1959, in his talk held at an American Physical Society meeting at the California Institute of Technology. On that occasion the 1965 Nobel Prize Laureate uttered the famous phrase "There is plenty of room at the bottom", meaning that there were vast opportunities for science and technology to expand into the study and exploitation of the properties of matter at the nanoscale (Feynman, 1960).

According to Renn & Roco (2006), "Nanoscience is the result of interdisciplinary cooperation between physics, chemistry, biotechnology, materials science and engineering towards studying assemblies of atoms and molecules" (p. 154). Actually, the appeal of NSTs is due to the fact that materials shaped at the dimensions of nanometres present properties that might strongly differ from those of the same bulk materials. Moreover, one can tune such properties if she has the ability to act on the shape and size of the exploited material. Summing up, the approach of NSTs basically relies on the specific dimensional features of materials.

Moreover, what is relevant in NSTs is the fact that several scientific areas, as well as sciences and technologies, are at the interplay. Several fields (starting from materials science, applied physics, device physics, physical chemistry, biology, engineering, and going to more specialistic fields such as supramolecular chemistry, interface science, catalysis, biophysics…) interact synergistically in order to advance scientific research and to prepare new technological discoveries that can be exploited into innovations (Roco, 2003b; 2003a).

This diverse and interdisciplinary approach has led across years to a large quantity of technological exploitation and of innovative applications of NSTs. Since the first years of their development the analysis of different NSTs research and innovation systems showed differences across countries in a dynamic where NSTs activities were still mainly performed by public research (Miyazaki & Islam, 2007). Ten years later the panorama was more complex and interconnected; despite the regional strengths and weaknesses, the development of NSTs gained complexity in terms of involvement of countries and of connections between subfields (Islam & Ozcan, 2017). Moreover, "Mapping of mature and emerging technologies within the nanotechnology field indicates future commercial applications" (p. 123).

Several applications of NST have been described across time. Ravichandran (2010) for instance describes a set of innovative technologies applied in the fields of food and of food processing. More than ten years later also Ashraf et al. (2021) perform an update on novel nanomaterials for food and agriculture industries. Innovations profiting of NST go from nutraceutical foods to nano-fertilizers, nano-pesticides and other technologies able to foster development of crop improvement and of the sustainability of farming. Also, water treatment can benefit of NST-based innovative technologies, such as Nano-adsorbents, nanostructured photocatalysts, metal nanoparticles and nanostructured membranes (Ajith et al., 2021).

Another field where technologies involving NSTs can be developed is oil and gas industry (Peng et al., 2018). Medicine and dentistry are probably the fields where most NST innovation are applied (Haleem et al., 2023; Elkassas & Arafa, 2017).

Summing up, NST nowadays find a wide range of applications in most fields of everyday life, notwithstanding the care that must be taken in terms of regulatory frameworks and of sustainability (Gottardo et al., 2021; Nasrollahzadeh et al., 2019).

2.2. International research collaborations: features, drivers and determinants

International research collaborations have been defined as an "emerging area of innovation studies" (K. Chen et al., 2019, p. 149). Since the beginning of the 1990s, studies on international scientific cooperation have tried to explore its features, for instance showing the increase of received citations in the set of collaborative papers (Narin et al., 1991). Science, between 2000 and 2015, has become increasingly global, generating a tripolar world where the main actors are Europe, Pacific Asia and North America (Gui et al., 2019). The patterns of collaboration depend on the scientific field, and also scientific development of countries has an effect on likelihood of collaboration (Gazni et al., 2012).

Several works have studied the determinants of international collaboration, both at institutional and at personal level. Collaboration might depend on geographical, cultural or historical reasons, such as being neighbouring countries, sharing language or presenting former relationships, such as being colonies of the same state (Finardi & Buratti, 2021). Yet Leydesdorff & Wagner (2008) did show the growth of international collaboration and of a global network of research. Wagner et al. (2017), almost ten years later, show the presence of different patterns in different scientific fields, and support to the hypothesis of a convergence at the global level. The network of international collaboration has been growing faster than exponentially in the years from 2000 to 2015 (Ribeiro et al., 2018).

Personal characteristics of researchers have an influence on their intensity of international collaboration. In particular, research performance and productivity are correlated with the international collaboration intensity, both when performance is measured with productivity and quality (Abramo et al., 2011a; 2011b). Also work experience abroad, in a study on Argentinean returnees, shows an effect in enhancing international cooperation (Jonkers & Cruz-Castro, 2013). Migrant scientists have larger international networks and a higher incidence of international collaboration, which in turn depends mostly from those performing a post-doc in a destination country (Scellato et al., 2015).

Some works deal specifically with research collaboration within sub-Saharan Africa, or some of its geographical subdivisions. The co-production of knowledge in selected sub-Saharan African countries has been examined by Onyancha & Maluleka (2011) through a bibliometric analysis. According to this study, collaborative research, and thus the contribution to the production of knowledge among studied African countries, looks minimal if compared to that with extra-African cones. A complementary result is that obtained, again via bibliometric analysis, by Schubert & Sooryamoorthy (2010) in their study of the specific case of collaboration between South Africa and Germany. Adopting a "centre-periphery" model the article shows that collaboration is explained by a theory of marginality and peripheral/central research units. South African scientists act strategically preferring collaboration with central regions rather than with other African countries. A more recent analysis by Dosso et al. (2023) shows the presence of a rise in inter-African collaborative science. Nevertheless, the path towards an integrated "African research area" is still on the go, notwithstanding the positive signals and emergence of networks.

Summing up, this short literature overview shows that international research collaboration is a multifaceted and evolving phenomenon. Its drivers can be many and different, depending at the macro/meso level on specific Country features and inter-Country relations, and at micro level again on relations and features of collaborating scientists. Regarding sub-Saharan Africa collaboration, most results show the fragility of the collaboration network, as well as the influence of external actors (countries) on the collaboration paths.

The present work builds on this batch of knowledge in order to respond to its research questions, devoted to a specific case of a country and of a scientific field, and namely being the study of the features of collaborations of South Africa in the field of NST, as well as their dependence from the structure of the internal scientific production and from the characteristics of the collaborating countries.

3. METHODOLOGY

This work exploits as its main dataset a bibliometric database, obtained via a search of scientific works on the online service Clarivate Web of Science® (WoS). The database has been built performing a country search for South Africa (field tag "CU = South Africa") on the WoS search system (search on WoS "core collection") and then selecting the "Web of Science Category" "Nanoscience nanotechnology" in order to refine the results. This simple refinement led to a dataset consisting of 2,276 bibliometric records, containing all the available information for each scientific work available on the WoS. The dataset was downloaded from WoS in December 2024. Due care was taken in order to build a meaningful and complete database.

Besides these bibliometric data, we extracted data regarding links between South Africa and its partner countries regarding scientific collaboration for the purpose of our empirical approach. Three complementary data sources were therefore used. The CEPII gravity database (Conte et al., 2022) enabled us to collect information on both spatial and temporal distances, along with language information. Furthermore, we gathered information on past colonial ties from the Authoritarian Regimes Dataset (Hadenius & Teorell, 2007; Wahman, Teoreill & Hadenius, 2013), and data for International Governmental Organizations (IGOs) membership from the International Governmental Organizations Data Set (Version 3.0) (Pevehouse, Nordstrom, McManus, & Jamison, 2020). Regarding the latter, we specifically focused on the following IGOs:

- The African Union (AU);
- The Southern African Development Community (SADC);
- The Southern African Customs Union (SACU);
- The Indian Ocean Rim Association (IORA).

We begin our analysis in 2005, in line with previous studies that identify the early 2000s as the initial exponential growth in NST (Masara, Van Der Poll & Maaza, 2021; Islam & Miyazaki, 2009), and 2005 in specific being a key turning point with the launch of South Africa's national nanotechnology strategy (Makhoba & Pouris, 2017).

Once downloaded the above-described data, these were imported into the Stata® statistics software in order to construct a panel dataset, with time series for each country, and perform apt statistical analysis.

4. DESCRIPTIVE STATISTICS AND BIBLIOMETRIC ANALYSIS

The first aspect investigated from our bibliometric database was the evolution in time of the weight of South African affiliations compared to foreign ones. To do so, we restructured the data so that each entry represents an author's affiliation for a given paper. To avoid overcounting repeated affiliations, we aggregated the data to retain only one instance of each affiliation per paper. That is, when more than one author with the same affiliation did collaborate to a single paper, we only counted the affiliation once. Additionally, per paper, we retained up to 10 affiliations in order to have a more coherent dataset. In this way we obtained a total of 6,201 paper-affiliations; out of these, 46.85% were domestic affiliations while 53.15% were foreign. Results are presented in Figure 1 and in Table 1.

The overall increasing trend in the number of affiliations is not surprising. On one hand, it reflects the overall growth in terms of worldwide number of scientific publications. On the other hand, it confirms the growing interest towards NSTs over time. However, what is interesting to note from this figure is that for almost a decade, South African affiliations outnumbered foreign ones, indicating that internal collaboration was prevalent over the external one. In contrast, foreign affiliations have surpassed domestic ones since 2017 in a significative way, highlighting a shift toward increasing international collaboration in the field.

This phenomenon supports the idea that international collaboration in the field has evolved in the last years. We therefore analyse foreign affiliations, considering first of all the evolution in

time at the broad continental level (Figure 2 and Table 2), and then at the country level (Figure 3) with a specific focus on the number of affiliations over the whole period, excluding South Africa and minor collaborators (i.e. countries with fewer than 10 affiliations).

Table 1. Count of paper-affiliations combinations in our dataset

Publication year	South African affiliations	Foreign affiliations
2005	9	3
2006	12	5
2007	32	14
2008	57	27
2009	54	38
2010	97	35
2011	98	45
2012	113	83
2013	112	106
2014	121	115
2015	124	124
2016	211	195
2017	192	222
2018	208	253
2019	248	253
2020	276	388
2021	234	295
2022	268	425
2023	213	266
2024	226	404
2005-2024	**2,905**	**3,296**

Table 2. Cumulative regional affiliations with South Africa

Publication year	Cumulative affiliations with Africa	Cumulative affiliations with Asia	Cumulative affiliations with Europe	Cumulative affiliations with America	Cumulative affiliations with Oceania
2005	10	0	1	1	0
2006	22	0	2	3	2
2007	55	0	10	4	6
2008	115	0	14	11	19
2009	172	0	22	18	39
2010	271	0	25	31	56
2011	369	2	32	52	71
2012	490	3	41	71	117
2013	606	4	66	112	152
2014	737	4	90	137	208
2015	876	4	100	189	255
2016	1,123	7	112	263	325
2017	1,338	7	136	360	403
2018	1,571	9	153	472	500
2019	1,863	12	165	584	582
2020	2,203	19	185	749	714
2021	2,473	28	207	913	778
2022	2,804	30	237	1 153	868
2023	3,053	36	257	1 306	919
2024	3,342	40	286	1 531	1 002
2005-2024	**23,493**	**205**	**2,141**	**7,960**	**7,016**

Figure 1. Internal and external collaboration, count of unique affiliations with other South African and foreign institutions

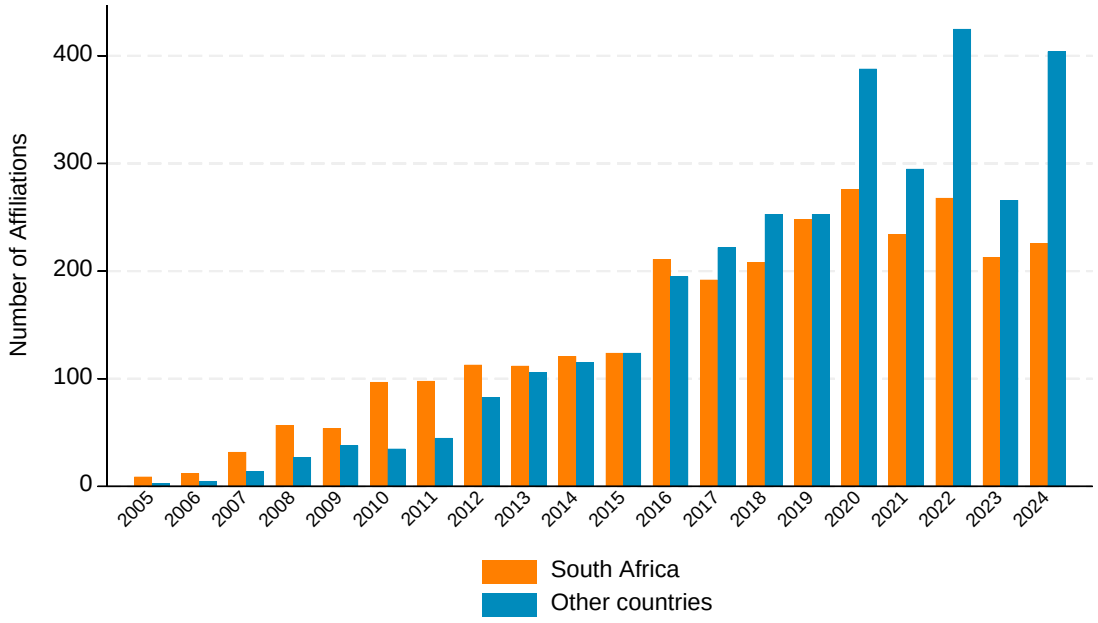


Figure 2. Cumulative regional affiliations with South Africa over time

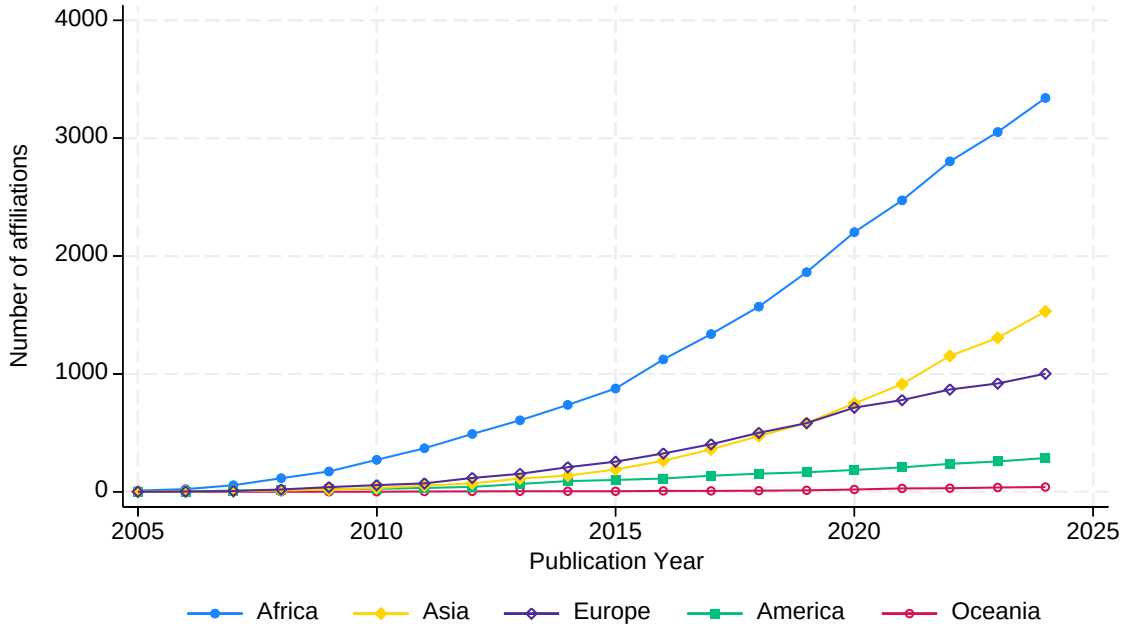
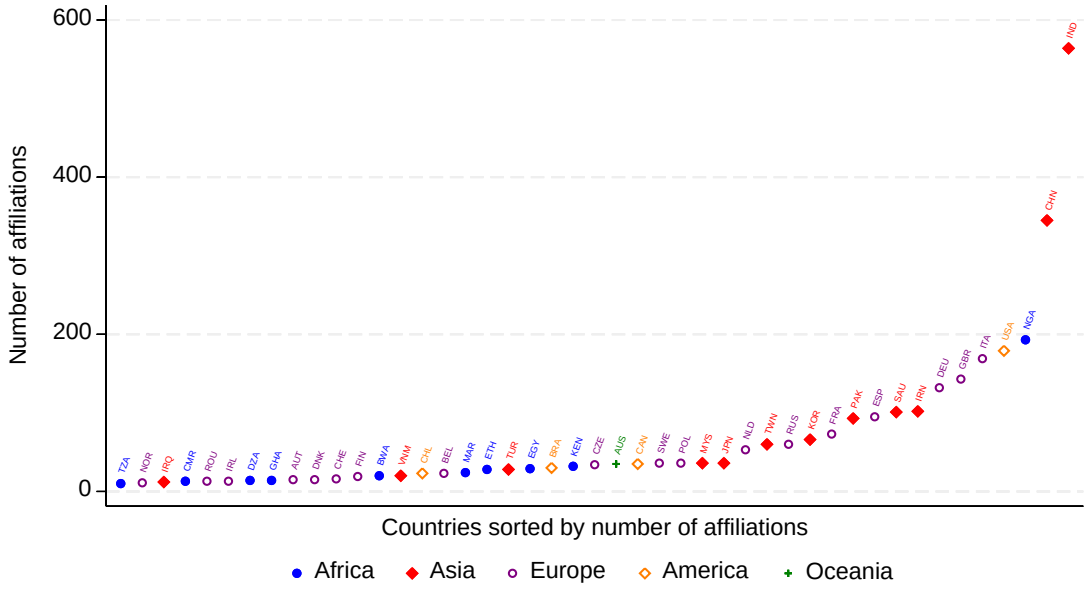


Figure 3. Main international collaborations with South Africa



*South Africa and minor collaborators (countries with fewer than 10 affiliations) are excluded.

To better understand the dynamics of international collaboration, we focus on the five main countries that most frequently co-authored publications with South Africa as observed in Figure 3, namely, India, China, the United States, Nigeria, and Italy. To this extent, Figure 4 highlights how collaboration with these key countries has evolved over time, revealing distinct patterns in the growth and intensity of bilateral scientific ties.

The presence of "returnees" is a relevant topic to explore when dealing with developing research systems such as those of African countries. The "returnee effect" refers to the impact that skilled professionals or academics (such as researchers, scientists, or students) have when they return to their home country after spending time abroad (Jonkers & Cruz-Castro, 2013; Wang et al., 2024). In the specific case of academia, the most common case is usually that of a South African young researcher who performed abroad either her Ph.D. and/or Post-doc. In order to disentangle the possible, relevant (in quantitative terms) presence of returnees coming back to South African universities the dataset was restructured with the aim of observing author's affiliations by paper. We then looked at the presence of South African affiliated authors who, across their career, have published articles using multiple affiliations. This fact is a possible proxy for the overall presence of South African returnees. Table 3 and Figure 5 present a summary of the yearly evolution of the number of authors with multiple, but at least one South African, affiliations. Moreover, we have disentangled the domestic, South African affiliations from the foreign ones in order to understand the magnitude and evolution of the phenomenon.

The obtained results show that the number of South African–affiliated authors with an additional foreign affiliation has followed a similar trajectory to those with only additional domestic affiliations. However, since 2021, the former have begun to outnumber the latter, a pattern that may indicate a potential returnee effect. The number of authors presenting both a domestic and foreign additional affiliation is, in principle, limited. Nevertheless, the phenomenon also presents some relevance for assessing the returnee effect. Finally, it is important to note that the phenomenon of returnees affects only a minority of scientists (Franzoni et al., 2012), which also calls for precaution when using our proxy for assessing the presence of returnees.

Figure 4. Main bilateral collaborations with South Africa

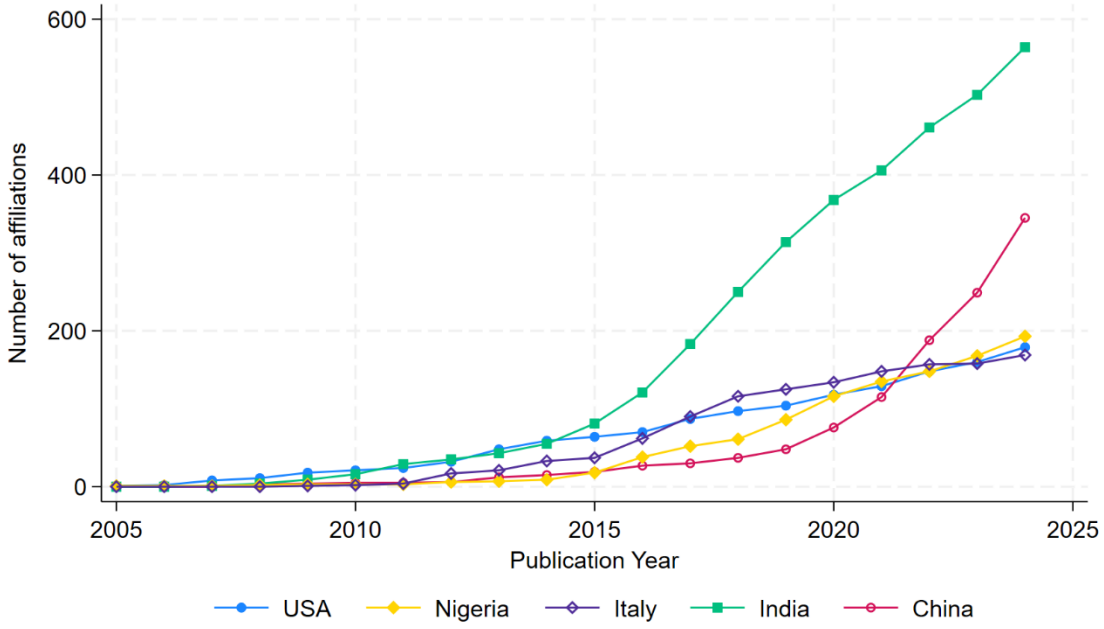
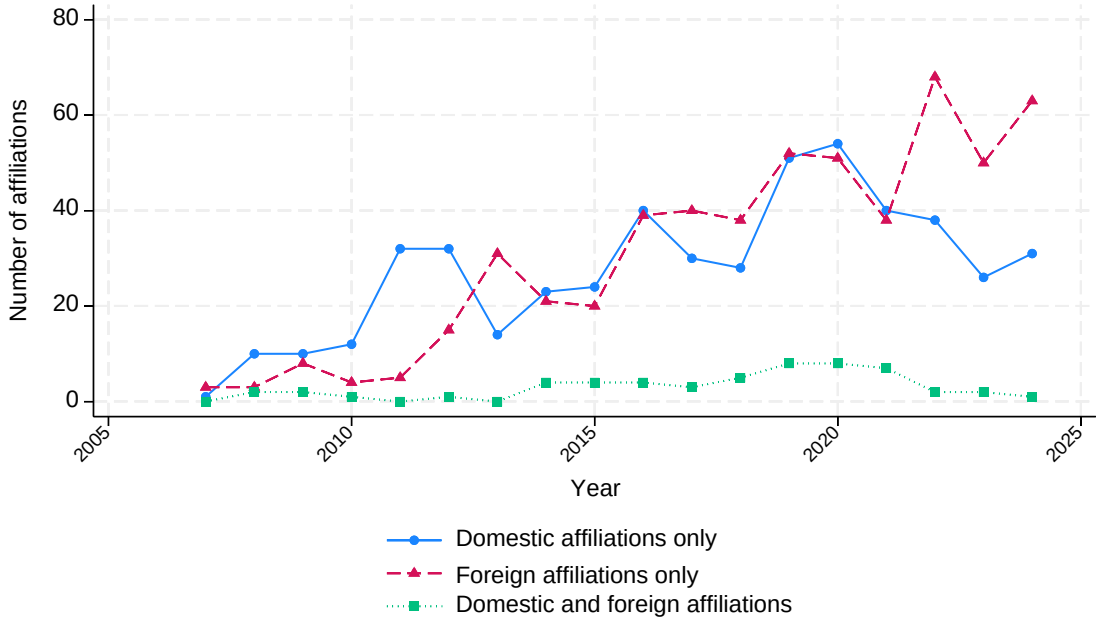


Table 3. Number of South African-affiliated authors with multiple affiliations

Publication year	Domestic affiliations	Foreign affiliations	Domestic and foreign affiliations	Total
2005	0	0	0	0
2006	0	0	0	0
2007	1	3	0	4
2008	10	3	2	15
2009	10	8	2	20
2010	12	4	1	17
2011	32	5	0	37
2012	32	15	1	48
2013	14	31	0	45
2014	23	21	4	48
2015	24	20	4	48
2016	40	39	4	83
2017	30	40	3	73
2018	28	38	5	71
2019	51	52	8	111
2020	54	51	8	113
2021	40	38	7	85
2022	38	68	2	108
2023	26	50	2	78
2024	31	63	1	95
Total	**496**	**549**	**54**	**1,099**

Figure 5. Evolution of the additional affiliations of South African affiliated authors



These findings raise the question of what drives South Africa's international scientific collaborations, and whether geographical or institutional factors play a role in shaping them. To address this, we complement the bibliometric analysis with an econometric one, based on a gravity model of scientific collaboration.

5. ECONOMETRIC ANALYSIS

5.1. The gravity model

Our main interest in the present study lies in explaining the features of a bilateral outcome, that of scientific co-publications in NSTs between South Africa and partner countries. To this end we deemed preferable to adopt a gravity model framework rather than a regression model of different nature. In this way, our econometric analysis follows a number of previous studies addressing international scientific collaboration using the gravity approach (Frenken et al. 2009; Hoekman, Frenken & van Oort 2009; Hoekman, Frenken & Tijssen 2010; Montobbio & Sterzi 2013; Zhang & Guo 2017; Avdeev 2021; Dosso, Cassi & Mescheba 2023), adapted from the gravity model largely employed to analyse trade flows based on Newton's law of universal gravitation (Tinbergen, 1962). The model posits that collaborative output between two countries is shaped by their "mass" (proxied by their individual research output, such as publication volumes) and inversely by the "distance" between them (e.g., geographic, cultural, or historical). Even though co-publications in NSTs do not represent a flow of goods, the adoption of the gravity model is justified by the dyadic structure of collaboration as well as by the importance of research capacity of both countries and the distance, that might act as a barrier to collaboration. Applied to our case of NSTs research collaboration, the model offers a robust empirical lens to assess how structural factors, such as South Africa's geographical and cultural proximity to partners, drive international co-authorship patterns.

In line with the literature (Montobbio & Sterzi, 2013; Dosso et al., 2023), we use Poisson pseudo-maximum likelihood (PPML) estimators to assess the determinants of international scientific collaboration in nanoscience between South Africa and its partner countries.

The general form of the gravity model's mathematical structure is commonly expressed as (Hoekman et al., 2010; Zhang & Guo, 2017):

$$C_{ijt} = A_i B_j F(d_{ij}) \quad (1)$$

where, C_{ijt} represents the interaction intensity (e.g., collaboration or flow) between entities *i* and *j*, while A_i and B_j denote their respective "mass" variables (e.g., research density). The function $F(d_{ij})$ refers to the separation between the two entities, where d_{ij} may reflect geographic, institutional, or other forms of distance.

By specifying functional forms for $F(d_{ij})$ and incorporating relevant covariates to this framework to adapt it to our research collaboration context, we get the following equation for our gravity model:

$$E[Collab_{SAit}] = A_{SAt}^{\alpha} A_{it}^{\beta} D_{SAi}^{\theta} \exp(\lambda T_{SAi} + \gamma L_{SAi}) \varepsilon^{SAit} \quad (2)$$

Where:

- $Collab_{SAit}$ is the number of NSTs co-publications between South Africa and country *i* at time *t*.
- A_{SAt} and A_{it} respectively, represent time-variant dimension: the masses in the gravity equation, in our case the total number of publications in the NST field of South Africa and of country *i* at time *t*.
- D_{SAi} represents the geographical distance between South Africa and country *i*. We use the population-weighted distance between each existing pair of most populated cities (harmonic mean).
- T_{SAi} measures the time difference in hours based on GMT offset between South Africa and country *i*.
- L_{SAi} captures historical/cultural ties between countries through a set of dummy variables:
  - $comlang\_ethno_{SAi}$: takes value 1 if countries share a common language spoken by at least 9% of the population,
  - $colonial\_tie_{SAi}$: takes value 1 if same post-1945 colonial relationship, and
  - IGO_{SAit}: takes value 1 if common membership of at least one IGO (AU, SADC, SACU, or IORA).
- ε^{SAit} is the error term.

The PPML is particularly suitable when the dependent variable is a count, and its distribution is highly skewed, as is the case with scientific collaboration counts. Its robustness to heteroskedasticity further justifies its application, with respect to an OLS model, in this context (Montobbio & Sterzi, 2013; Dosso et al., 2023). Moreover, the dataset includes a substantial number of zero values (69,7%) for the country-year pairs with no observed collaboration. These zeros are meaningful and not due to rounding or reporting errors, and as noted by Santos Silva & Tenreyro (2006), PPML offers a natural way to handle such zero outcomes without requiring data transformation or deletion, which justifies again the use of the estimation method over a simple OLS. Finally, as observation in pairs of countries are likely to be dependent across years, robust standard errors are clustered at the partner country level to control for correlation of the error terms in the panel (Montobbio & Sterzi, 2013; Dosso et al., 2023).

Given that our primary interest lies in estimating the effects of structural variables such as geographical distance, colonial ties, and joint membership in IGOs, we opt for a model without fixed effects. This allows for the identification of time-invariant dyadic variables, which would otherwise be absorbed by partner-country and year fixed effects (Montobbio & Sterzi, 2013). It

is important to note that, in principle, IGO membership can vary over time. However, for the specific organizations considered in this study, there is only one observed case of a change: the Democratic Republic of Congo, which was a member of the African Union in 2005 but later withdrew. Given that this is the only instance of temporal variation in IGO membership within the sample, the variable IGO_{SAit} can be reasonably treated as time-invariant.

The presence of fixed effect still appears in the estimation equation as we ran one specification with partner-country and year fixed effects to assess the robustness of these results and to account for potential unobserved heterogeneity across partner countries and over time.

In line with standard gravity model practice, we transform the mass variables – total NSTs publications in South Africa and in the partner country – as well as the geographical distance into their natural logarithmic form. This reflects the expected diminishing marginal effects of scientific size and spatial distance on collaboration intensity, and allows for interpretation of coefficients as elasticities. To account for the lack of NSTs publications in a number of country-years (13% of observations), we use the transformation *ln(x + 1)* (in this case: *ln(total_pub + 1)*). As Wooldridge (2012, p.194) explains, this is a common solution when nonnegative variables include zeros, allowing interpretation to remain approximately consistent with log-linear models. Indeed, it avoids considering these observations as missing values, thus dropping them, preventing in this way from selection bias. Moreover, the observations are preserved and mapped to zero in the log scale (since *ln(1) = 0*), ensuring that the model captures the full variation in research collaboration across countries and time.

The time difference variable is a discrete measure ranging from 0 to 12, with limited variation across observations. For interpretability and to avoid losing countries that share the same time zone with South Africa (for which time difference equals zero and the logarithm is undefined), the variable is retained in level form rather than transformed.

The remaining variables are included in level form as they are either categorical or binary indicators.

Table 4 reports the name, basic summary statistics and data sources of the variable included in our gravity model.

Table 4. Summary statistics and data sources

Variable	Data sources	Obs.	Mean	Std. dev.	Min.	Max.
collab	Web of Science	2060	1.036408	3.073668	0	46
log(total_pub$_i$)	Web of Science	2060	3.790811	2.617723	0	13.05045
log(total_pub_SA)	Web of Science	2060	4.443447	.7955656	2.484907	5.342334
log(dist_harmonic)	CEPII dataset	2060	8.83728	.638049	5.945421	9.594173
time_diff	CEPII dataset	2060	2.419903	2.513976	0	10
colonial_tie	ARD dataset	2060	.3009709	.4587914	0	1
comlang_ethno	CEPII dataset	2060	.2912621	.4544544	0	1
igo	IGO V3 dataset	2060	.3592233	.4798893	0	1
au	IGO V3 dataset	2060	.2519417	.4342334	0	1
sacu	IGO V3 dataset	2060	.0291262	.1682011	0	1
sadc	IGO V3 dataset	2060	.0873786	.2824577	0	1
iorarc	IGO V3 dataset	2060	.1359223	.3427893	0	1

5.2. Results

Table 5 presents the results of our gravity model. The first specification of the gravity model estimates the baseline gravity model, including only the "masses" – the total number of NST publications in both South Africa and the partner country – and the geographic distance, measured as the population-weighted distance between most populated cities, using the harmonic mean,

which is the theory consistent way to measure distance between two countries according to the gravity database (Conte, Cotterlaz, & Mayer, 2022, p.13). As expected, both mass variables have positive and significant effects: the more active South Africa and its partners are in NST research, the more likely they are to collaborate, while distance drives negatively collaboration patterns ($\beta = -0.629, \mathrm{p} < 0.01$), a 1% increase in geographic distance between South Africa and the country partner is associated with a 0.63% decrease in the number of NST co-authored publications.

With the 2nd specification of the model, we followed Montobbio & Sterzi (2013) by controlling whether temporal distance, in other words the time differences between countries, could lead to high coordination costs of (virtual) interactions for researchers that would, in turn, deter collaboration. In their paper, Montobbio & Sterzi (2013) go even deeper in the argument by stating that "geographic distance can be considered as a proxy of face-to-face interaction cost and time zone difference a proxy of virtual interaction cost that can substitute direct personal contacts." (p. 285). In our case, the coefficient for time zone difference is statistically insignificant, suggesting that collaboration in NSTs research between South Africa and its partners is not strongly affected by temporal distance. This result aligns with the observation that two of South Africa's top collaborators, i.e. China and the USA, are in time zones that differ by six and seven hours, respectively (see Table 6). These partnerships may have adapted to time zone challenges through asynchronous communication and institutional links that enabled trust from prior collaboration experiences, better coordination skills and lower reliance on real-time interactions. The divergence in main partnering countries with the bibliometric analysis is justified by the level of analysis. In the previous section, we focused on unique affiliations per paper, where if multiple authors from different affiliations within the same country were present, each of those affiliations was counted separately. In contrast, here the econometric analysis measures collaborations at the country level, counting each country only once per paper regardless of how many affiliations or authors it had in that publication.

Table 5. Gravity model estimations, PPML estimates

Dependent variable: $Collab_{SAit}$	**(1)**	**(2)**	**(3)**	**(4)**
Tot. SA Publications	1.276***	1.304***	1.243***	0
	(0.127)	(0.127)	(0.122)	(.)
Tot. Partner Pubs	0.428***	0.387***	0.475***	0.398**
	(0.0802)	(0.0655)	(0.0728)	(0.195)
Harmonic Distance	-0.629***		-0.558**	0
	(0.230)		(0.281)	(.)
Time Zone Difference		0.00395	0.00890	0
		(0.0421)	(0.0516)	(.)
Colonial Tie			-0.381	0
			(0.349)	(.)
Common Ethnic Lang.			0.177	0
			(0.313)	(.)
IGO Membership			0.827**	0
			(0.395)	(.)
_cons	-2.743	-8.295***	-3.745	-1.391
	(1.902)	(0.657)	(2.376)	(1.372)
Observations	2060	2060	2060	2060

Standard errors in parentheses
* $p < 0.1$, ** $p < 0.05$, *** $p < 0.01$

Table 6. South Africa's main collaborating partners in NST publications

Top 5 partners	Number of publications with S.A.	Time Difference with S.A.
India	289	3,5
China	192	6
United States of America	143	7
Nigeria	129	1
United Kingdom of Great Britain and Northern Ireland	105	2

The 3rd specification includes both the temporal and geographical distances, where the patterns already observed in the previous models confirm, with geographic distance still significantly negative and temporal distance not significant. Additionally, the variables capturing cultural and institutional proximity between countries were added, namely common colonial ties, shared language, and joint membership in IGOs. As Dosso et al. (2023) we chose the ethnic language dummy of the CEPII dataset (if countries share a common language spoken by at least 9% of the population the dummy takes the value of 1, otherwise 0) because the official language dummy is usually already reflected in the common colonial ties dummy. Only IGO membership, in this case AU, SADC, SACU, or IORARC has a statistically significant effect ($\beta = 0.827$, $p < 0.05$), suggesting that formal institutional ties positively influence collaborative activity in NSTs. This aligns with previous findings (Dosso et al., 2023), which highlight the role of regional organizations in fostering cross-border scientific collaboration.
The effects of colonial ties and common language are positive but not statistically significant, possibly due to overlaps with other proximity measures or limited variation across country pairs.

The last specification was run with fixed effects, as a robustness check. As expected, the inclusion of country-pair fixed effects absorbs the variation in structural variables. Only the total number of publications of the partner country (ln_total_pub) remains identified and significant, as it varies across countries and years, which confirms the validity of the gravity framework.

To summarize, across all specifications, the "mass" variables consistently and significantly enhance collaboration levels. Specifically, the augmented model (3) shows a 1% increase in the publications of South Africa is associated with a 1.243% increase in co-publications, and a 1% increase in the publications of South Africa's partners is associated with a 0.475% increase in the total number of co-authored papers. Geographical distance plays a clear deterrent role, while temporal distance does not appear to matter significantly. Institutional ties, with memberships to common IGOs, enhance collaboration, suggesting the importance of regional and multilateral research frameworks.

6. CONCLUSIONS

The aim of this paper is to explore the scientific production and national and international collaboration patterns of an African country, South Africa, chosen as a relevant case due to its scientific positioning in terms of production of research papers and networking. The analysis contributes to filling a gap in the literature since it is performed through a relevant scientific and technological field, that of nanosciences and nanotechnologies, relatively unexplored in Africa. The main dataset is built around scientific product data, paired with relevant data relative to the countries collaborating with South Africa.

The combined use of bibliometric and econometric approaches provides a novel perspective on both the descriptive trends and the structural determinants of collaboration.

The descriptive statistical and bibliometric analysis, conducted at the paper-affiliation level, shows the presence of an evolution in the collaboration pattern of South Africa. International collaboration grows faster than national, and outnumbers it in 2017. Also, the collaboration with

the five more relevant countries (USA, Nigeria, Italy, India, China) follows different patterns across time. Our analysis suggests some evidence of a potential returnee effect, as South African-affiliated authors with additional foreign affiliations have recently become more numerous than those with only domestic ones, raising the interest for a deeper study. However, since this finding relies on a proxy measure, it should be taken with precaution.

Coming to the econometric analysis, conducted at the paper-country level, we exploited a gravity model with Poisson pseudo-maximum likelihood estimators, supported by a wide stream of previous literature, to disentangle the factors underlying international scientific collaboration pattern. Results show that, ultimately, the most relevant factor that affects negatively scientific collaboration is geographic distance. On the other hand, the positive effect of scientific production by partnering country is imaginable and rather trivial. The only other variable presenting a statistically significant effect is IGO membership. This suggests that formal, institutional ties might have a positive influence in scientific collaboration, aligning with previous findings (Dosso et al., 2023).

This work leaves also space to further deepening. In particular, it will be interesting to study the whole collaboration patterns between every country in the African continent, adapting this unilateral gravity model to a multilateral one. Moreover, it would be interesting to study the effect of past collaborations (like Montobbio & Sterzi, 2023, do) to see the effects of collaboration patterns. The observation of research and investments in NSTs in the private sphere across countries could also be further explored, to see whether research collaboration follows a similar trend. Finally, the model could be extended to other meaningful scientific fields, either looking at more specific fields (cf. Masara et al. 2021; Makhoba & Pouris, 2017) or further widening the scope of the research.

7. References

Abramo, G., D'Angelo, C. A., & Solazzi, M. (2011a). Are researchers that collaborate more at the international level top performers? An investigation on the Italian university system. *Journal of Informetrics*, *5*(1), pp. 204-213. https://doi.org/10.1016/j.joi.2010.11.002

Abramo, G., D'Angelo, C.A., & Solazzi, M. (2011b). The relationship between scientists' research performance and the degree of internationalization of their research. *Scientometrics*, *86*(3), pp. 629-643. https://doi.org/10.1007/s11192-010-0284-7

Ajith, M.P., Aswathi, M., Priyadarshini, E., & Rajamani, P. (2021). Recent innovations of nanotechnology in water treatment: A comprehensive review. *Bioresource Technology*, 342, 126000. https://doi.org/10.1016/j.biortech.2021.126000

Ashraf, S.A., Siddiqui, A.J., Elkhalifa, A.E.O., Khan, M.I., Patel, M., Alreshidi, M., Moin, A., Singh, R., Snoussi, M., & Adnan, M. (2021). Innovations in nanoscience for the sustainable development of food and agriculture with implications on health and environment. *Science of The Total Environment*, 768, 144990. https://doi.org/10.1016/j.scitotenv.2021.144990

Avdeev, S. (2021). International collaboration in higher education research: A gravity model approach. *Scientometrics*, *126*(7), pp. 5569-5588. https://doi.org/10.1007/s11192-021-04008-8

Balzani, V. (2005). Nanoscience and Nanotechnology: A Personal View of a Chemist. *Small*, *1*(3), Article 3. https://doi.org/10.1002/smll.200400010

Chen, H., Roco, M.C., Son, J., Jiang, S., Larson, C.A., & Gao, Q. (2013). Global nanotechnology development from 1991 to 2012: Patents, scientific publications, and effect of NSF funding. *Journal of Nanoparticle Research*, *15*(9), Article 9. https://doi.org/10.1007/s11051-013-1951-4

Chen, K., Zhang, Y., & Fu, X. (2019). International research collaboration: An emerging domain of innovation studies? *Research Policy*, *48*(1), pp. 149-168. https://doi.org/10.1016/j.respol.2018.08.005

Conte, M., Cotterlaz, P., & Mayer, T. (2022). *The CEPII gravity database* (Working Papers 2022-05). CEPII.

Dosso, M., Cassi, L., & Mescheba, W. (2023). Towards regional scientific integration in Africa? Evidence from co-publications. *Research Policy*, *52*(1), 104630. https://doi.org/10.1016/j.respol.2022.104630

Elkassas, D., & Arafa, A. (2017). The innovative applications of therapeutic nanostructures in dentistry. *Nanomedicine: Nanotechnology, Biology and Medicine*, *13*(4), pp. 1543-1562. https://doi.org/10.1016/j.nano.2017.01.018

Feynman, R.P. (1960). There's Plenty of Room at the Bottom. An invitation to open up a new field of physics. *Engineering and Science*, *23*(5), pp. 22-36.

Finardi, U. (2013). Clustering Research, Education, and Entrepreneurship: Nanotech Innovation at MINATEC in Grenoble. *Research-Technology Management*, *56*(1), Article 1. https://doi.org/10.5437/08956308X5601040

Finardi, U. (2015). Scientific collaboration between BRICS countries. *Scientometrics*, *102*(2), Article 2. https://doi.org/10.1007/s11192-014-1490-5

Finardi, U. (2023). Nanotechnologies and Nanosciences in a Regional Context: The Case of Italian Region Piedmont. *L'industria*, 1. https://doi.org/10.1430/107735

Finardi, U., & Buratti, A. (2016). Scientific collaboration framework of BRICS countries: An analysis of international coauthorship. *Scientometrics*, *109*(1), Article 1. https://doi.org/10.1007/s11192-016-1927-0

Finardi, U., & Buratti, A. (2021). The strength of international scientific ties: A novel analysis of inter-Country coautorship. *Ciência Da Informação*, *50*(1), Article 1. https://revista.ibict.br/ciinf/article/view/5254

Finardi, U., & Lamberti, C. (2021). Diversity and interdisciplinarity in nanoscience and nanotechnology: A time-related analysis of the subject category. *Journal of Nanoparticle Research*, *23*(1), 7. https://doi.org/10.1007/s11051-020-05119-8

Franzoni, C., Scellato, G., & Stephan, P. (2012). Foreign-born scientists: Mobility patterns for 16 countries. *Nature Biotechnology*, *30*(12), pp. 1250-1253. https://doi.org/10.1038/nbt.2449

Frenken, K., Hoekman, J., Kok, S., Ponds, R., van Oort, F., & van Vliet, J. (2009). Death of distance in science? A gravity approach to research collaboration. In A. Pyka & A. Scharnhorst (eds.), *Innovation networks*, Chapter 3 (pp. 43-57). Springer.

Gazni, A., Sugimoto, C.R., & Didegah, F. (2012). Mapping world scientific collaboration: Authors, institutions, and countries. *Journal of the American Society for Information Science and Technology*, *63*(2), pp. 323-335. https://doi.org/10.1002/asi.21688

Gottardo, S., Mech, A., Drbohlavová, J., Małyska, A., Bøwadt, S., Riego Sintes, J., & Rauscher, H. (2021). Towards safe and sustainable innovation in nanotechnology: State-of-play for smart nanomaterials. *NanoImpact*, 21, 100297. https://doi.org/10.1016/j.impact.2021.100297

Gui, Q., Liu, C., & Du, D. (2019). Globalization of science and international scientific collaboration: A network perspective. *Geoforum*, 105, pp. 1-12. https://doi.org/10.1016/j.geoforum.2019.06.017

Hadenius, A., & Teorell, J. (2007). Pathways from authoritarianism. *Journal of Democracy*, *18*(1), pp. 143-157.

Haleem, A., Javaid, M., Singh, R.P., Rab, S., & Suman, R. (2023). Applications of nanotechnology in medical field: A brief review. *Global Health Journal*, *7*(2), pp. 70-77. https://doi.org/10.1016/j.glohj.2023.02.008

Hoekman, J., Frenken, K., & Tijssen, R.J.W. (2010). Research collaboration at a distance: Changing spatial patterns of scientific collaboration within Europe. *Research Policy*, *39*(5), pp. 662-673. https://doi.org/10.1016/j.respol.2010.01.012

Hoekman, J., Frenken, K., & Van Oort, F. (2009). The geography of collaborative knowledge production in Europe. *The Annals of Regional Science*, *43*(3), pp. 721-738. https://doi.org/10.1007/s00168-008-0252-9

Islam N. & Miyazaki K. (2009). Nanotechnology innovation system: understanding hidden dynamics of nanoscience fusion trajectories. *Technol Forecast Soc Change*, 76, pp. 128-140. https://doi.org/10.1016/j.techfore.2008.03.021

Islam, N., & Ozcan, S. (2017). The management of nanotechnology: Analysis of technology linkages and the regional nanotechnology competencies. *R&D Management*, *47*(1), Article 1. https://doi.org/10.1111/radm.12161

Jeenah, M., & Pouris, A. (2008). South African research in the context of Africa and globally. *South African Journal of Science*, *104*(9-10), pp. 351-354. Scopus.

Jonkers, K., & Cruz-Castro, L. (2013). Research upon return: The effect of international mobility on scientific ties, production and impact. *Research Policy*, *42*(8), pp. 1366-1377. https://doi.org/10.1016/j.respol.2013.05.005

Leydesdorff, L., & Wagner, C.S. (2008). International collaboration in science and the formation of a core group. *Journal of Informetrics*, *2*(4), pp. 317-325. https://doi.org/10.1016/j.joi.2008.07.003

Makhoba, X., & Pouris, A. (2016). Scientometric assessment of selected R&D priority areas in South Africa: A comparison with other BRICS countries. *African Journal of Science, Technology, Innovation and Development*, *8*(2), pp. 187-196. https://doi.org/10.1080/20421338.2016.1147205

Makhoba, X., & Pouris, A. (2017). Bibliometric analysis of the development of nanoscience research in South Africa. *South African Journal of Science*, *113*(11-12), 9. https://doi.org/10.17159/sajs.2017/20160381

Mangematin, V., & Walsh, S. (2012). The future of nanotechnologies. *Technovation*, *32*(3), pp. 157-160. https://doi.org/10.1016/j.technovation.2012.01.003

Masara, B., Van Der Poll, J.A., & Maaza, M. (2021). A nanotechnology-foresight perspective of South Africa. *Journal of Nanoparticle Research*, *23*(4), 92. https://doi.org/10.1007/s11051-021-05193-6

Montobbio, F., & Sterzi, V. (2013). The Globalization of Technology in Emerging Markets: A Gravity Model on the Determinants of International Patent Collaborations. *World Development*, 44, pp. 281-299. https://doi.org/10.1016/j.worlddev.2012.11.017

Miyazaki, K., & Islam, N. (2007). Nanotechnology systems of innovation. An analysis of industry and academia research activities. *Technovation*, *27*(11), pp. 661-675. https://doi.org/10.1016/j.technovation.2007.05.009

Narin, F., Stevens, K., & Whitlow, E.S. (1991). Scientific co-operation in Europe and the citation of multinationally authored papers. *Scientometrics*, *21*(3), Article 3. https://doi.org/10.1007/BF02093973

Nasrollahzadeh, M., Sajadi, S.M., Sajjadi, M., & Issaabadi, Z. (2019). Chapter 4. Applications of Nanotechnology in Daily Life. In M. Nasrollahzadeh, S.M. Sajadi, M. Sajjadi, Z. Issaabadi, & M. Atarod (eds.), *Interface Science and Technology* (vol. 28, pp. 113-143). Elsevier. https://doi.org/10.1016/B978-0-12-813586-0.00004-3

Onyancha, O.B., & Maluleka, J.R. (2011). Knowledge production through collaborative research in sub-Saharan Africa: How much do countries contribute to each other's knowledge output and citation impact? *Scientometrics*, *87*(2), pp. 315-336. https://doi.org/10.1007/s11192-010-0330-5

Peng, B., Tang, J., Luo, J., Wang, P., Ding, B., & Tam, K.C. (2018). Applications of nanotechnology in oil and gas industry: Progress and perspective. *The Canadian Journal of Chemical Engineering*, *96*(1), pp. 91-100. https://doi.org/10.1002/cjce.23042

Pevehouse, J.C., Nordstrom, T., McManus, R.W., & Jamison, A.S. (2020). Tracking organizations in the world: The Correlates of War IGO Version 3.0 datasets. *Journal of Peace Research*, *57*(3), pp. 492-503.

Ravichandran, R. (2010). Nanotechnology Applications in Food and Food Processing: Innovative Green Approaches, Opportunities and Uncertainties for Global Market. *International Journal of Green Nanotechnology: Physics and Chemistry*, *1*(2), pp. 72-96. https://doi.org/10.1080/19430871003684440

Renn, O., & Roco, M.C. (2006). Nanotechnology and the need for risk governance. *Journal of Nanoparticle Research*, *8*(2), pp. 153-191. https://doi.org/10.1007/s11051-006-9092-7

Ribeiro, L.C., Rapini, M.S., Silva, L.A., & Albuquerque, E.M. (2018). Growth patterns of the network of international collaboration in science. *Scientometrics*, *114*(1), pp. 159-179. https://doi.org/10.1007/s11192-017-2573-x

Roco, M.C. (2003a). Converging science and technology at the nanoscale: Opportunities for education and training. *Nature Biotechnology*, 21, pp. 1247-1249. https://doi.org/10.1038/nbt1003-1247

Roco, M.C. (2003b). Nanotechnology: Convergence with modern biology and medicine. *Current Opinion in Biotechnology*, *14*(3), Article 3. https://doi.org/10.1016/S0958-1669(03)00068-5

Roco, M.C., & Bainbridge, W.S. (2002). Converging Technologies for Improving Human Performance: Integrating from the Nanoscale. *Journal of Nanoparticle Research*, *4*(4), Article 4. https://doi.org/10.1023/A:1021152023349

Santos Silva, J.M.C., Tenreyro, S. (2006). The log of gravity. *The Review of Economics and statistics*, 88 (2006), pp. 641-658. https://doi.org/10.1162/rest.88.4.641

Scellato, G., Franzoni, C., & Stephan, P. (2015). Migrant scientists and international networks. *Research Policy*, *44*(1), pp. 108-120. https://doi.org/10.1016/j.respol.2014.07.014

Schubert, T., & Sooryamoorthy, R. (2010). Can the centre-periphery model explain patterns of international scientific collaboration among threshold and industrialised countries? The case of South Africa and Germany. *Scientometrics*, *83*(1), pp. 181-203. https://doi.org/10.1007/s11192-009-0074-2

Sooryamoorthy, R. (2019). Scientific knowledge in South Africa: Information trends, patterns and collaboration. *Scientometrics*, *119*(3), pp. 1365-1386. https://doi.org/10.1007/s11192-019-03096-x

Tinbergen, J. (1962). *Shaping the world economy. Suggestions for an international economic policy*. The 20th Century Fund.

Wagner, C.S., Whetsell, T.A., & Leydesdorff, L. (2017). Growth of international collaboration in science: Revisiting six specialties. *Scientometrics*, *110*(3), pp. 1633-1652. https://doi.org/10.1007/s11192-016-2230-9

Wahman, M., Teorell, J., & Hadenius, A. (2013). Authoritarian regime types revisited: Updated data in comparative perspective. *Contemporary Politics*, *19*(1), pp. 19-34.

Wang, Z., Hanley, N., Kwak, J., Vari-Lavoisier, I., Al Hussein, M., Sanchez Tyson, L., Akkad, A., & Chankseliani, M. (2024). How do international student returnees contribute to the development of their home countries? A systematic mapping and thematic synthesis. International *Journal of Educational Research*, 125, 102330. https://doi.org/10.1016/j.ijer.2024.102330

Wooldridge, J.M. (2012). *Introductory Econometrics: A Modern Approach*. 5th Edition, Cengage Learning.

Zhang, C., & Guo, J. (2017). China's international research collaboration: Evidence from a panel gravity model. *Scientometrics*, *113*(2), pp. 1129-1139. https://doi.org/10.1007/s11192-017-2513-9

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Numeri precedenti/Previous issues

This paper examines the dynamics of national and international research collaboration in nanosciences and nanotechnologies (NSTs) in South Africa, a country studied for its distinctive position – at continental and world level – in global scientific production and cross-border partnerships. The main objective is to map collaboration patterns and identify the key determinants of international scientific co-productions.

We employ both bibliometric and econometric approaches. The bibliometric analysis, based on publication data from the Clarivate Web of Science®, captures trends in internal and external collaboration, while the econometric analysis applies a gravity model to our dataset, which links publication records with country-level information from the CEPII gravity database, the ARD Data Set and the IGO Data Set.

Descriptive statistical findings reveal a shift over time, with international collaboration outpacing domestic collaboration. As for the econometric analysis, geographic proximity exerts the strongest positive influence on collaboration intensity, with higher levels of scientific production in partner countries positively associated with collaboration. In addition, shared membership in intergovernmental organizations emerges as the only other relevant factor in explaining co-production. These results highlight both the global integration of South African NSTs research and the persistent structural barriers that shape its collaborative landscape.

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